

Reducing Environmental Impact from Manufacturing – three Industrial Cases for the Manufacturing of ‘Green’ Products

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Abstract

There is a gigantic need for technology and strategies that will reduce CO₂ emissions globally. This paper presents three industrial cases in Sweden where manufacturing of ‘green’ products are analysed and solutions are presented where environmental impact from manufacturing is reduced. The cases represent a conceptual product, a manufacturing ready product and an update of an existing product. The cases also build the base for presenting a draft analysis scheme for designing a more environmentally sustainable production system. The cases and the proposed analysis scheme are discussed in the context of designing a socially, economically and environmentally sustainable production system.

Keywords:

Manufacturing, Sustainable development, Product

1 INTRODUCTION

There is a long seen need for an environmental, economic and social sustainable society, meeting the needs of the present without compromising the ability of future generations to meet their own needs [1]. Focusing on environmental sustainability, has led to emerging legislation and industrially accepted emission targets, on an overall level represented by e.g. the Kyoto protocol.

Meanwhile, a global wealth increase is evident. Through the means of globalisation, values are created worldwide with a 60 % increase of GDP in current prices over 1996-2006 [2]. By increased welfare the product demand and manufacturing activity increases – we have seen a 43 % increase in current prices of manufacturing activities worldwide 1996-2006. [3] Over the recent decade, for instance China has seen an unprecedented manufacturing increase.

These two trends, the need for sustainability and the globally increasing product demands and manufacturing activities drive a gigantic need for technology and strategies that globally reduces environmental impact of manufacturing [4]. There is a need of large improvements in terms of resource productivity – ‘doing more with less’. The challenge is to reduce non-renewable material and energy usage in a fast increasing economic activity.

This paper approaches the need of resource productivity from the view of production system design. The objective is to illustrate production system design aspects for the manufacturing of ‘green’ products, i.e. products that by its usage reduces the total environmental load. Three cases build the base for presenting a draft analysis scheme for designing a more environmentally sustainable production system. Finally, the cases and the proposed analysis scheme are discussed in the context of designing a socially, economically and environmentally sustainable production system.

2 ENVIRONMENTAL IMPACT ANALYSIS

Life cycle engineering and various eco design strategies have for a long time been proposed and applied for the design of products. [5-9]. However, specific **production system design** schemes for integration of environmental concerns into the traditional design process are more rare.

2.1 Life Cycle Assessment (LCA) and tools

Life cycle assessment or life cycle analysis (LCA) is a well established family of methods to assess a product’s environmental impact from cradle to grave [9]. The method to do an LCA has been standardized and put as a subgroup under ISO 14000. In ISO 14040-45 the LCA’s ‘how to’, ‘what’ and ‘why’ are described. Figure 1 illustrates the underlying principle of LCA, that all phases of the product life cycle effect the environment.

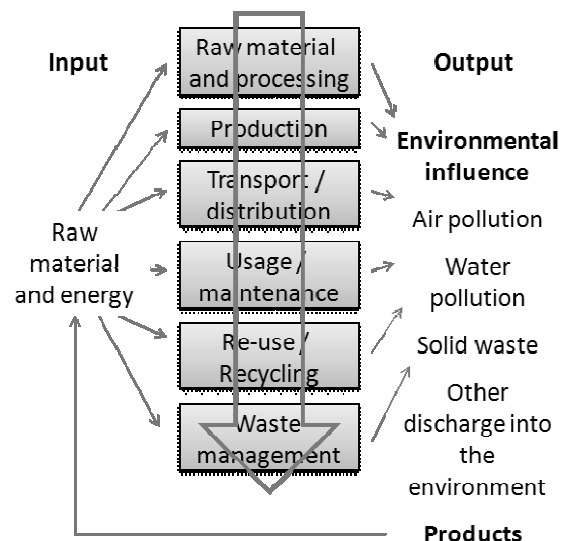


Figure 1. The life cycle of a product

3 RESEARCH SETUP

3.1 Objective

The objective of this study was to put focus on the production system design and analyse it with regard to environmental impact. To our experience, product designers are relatively well equipped with LCA-tools and similar, however the production engineering and production system designer are often less supported by methods and tools for analysing and minimising environmental impact. This research should be seen as an effort in reaching decision support tools also applicable in the production design phase.

3.2 Methodological considerations

In order to analyse and illustrate the production system design from an environmental analysis perspective, three industrial cases were carried out during the summer 2008. Different project teams were set up, running in parallel with a synchronized phased project scheme in order to exchange experiences.

The research has been based on three industry cases, leading to a big impact from the temporal, cultural and social context of these cases on the results. This is however always the case in this kind of case-based research, where analytical generalisation is used in contrast to research based on statistical generalisations.

Yin points out four criteria for judging the quality of case study research: Construct Validity, Internal Validity, External Validity and Reliability [17].

In this research, being an exploratory first phase towards a method to be validated, the external validity (i.e. the possibility to generalise outside the studied cases) is not obvious. The reliability of propositions is also obviously not verified at this point.

However, these four aspects of validity and reliability are important aspects to consider in the total research setup, where this is a first phase. The case selection is for instance central to span the solution space and in the end establish an external validity.

3.3 Case selection

The cases are different with regard to phases in the production system design process; one is for a conceptual product; one is for a manufacturing ready product and one concerns an update of an existing product. The companies for the first two cases were small start-up companies where the product were a part of the first family of products. In the third case the company was a joint venture based upon this specific product. The active owners of the venture were however, two well established global manufacturing companies.

4 CASE DESCRIPTION

Three cases were studied, representing different aspects of production system design.

4.1 Case 1: Power Aware Cord

One objective of this case was to present a check list for sustainable product realization of the product Power Aware Cord (PAC). The project also concluded comments on product design and regulations and directives for the European market.

The PAC product was developed in a research project where the research institute 'Interactive Institute' analysed various ways to visualise energy consumption. On solution was the Power Aware Cord, where the power flowing through the cord is visualized by the light intensity of the cord, see figure 5.



Figure 5. The Power Aware Cord.

The case is part of a total effort in commercialising the product. In analysing the product design, regulations and directives as well as production system design possibilities, following general conclusion were made:

Since PAC is a product that should visualise energy usage, leading to a decrease of energy usage and thus environmental impact, the product itself should be manufactured in an environmental friendly manner as possible. Material selection should be based on the REACH directive, disposal handling based on RoHS and WEEE directive and finally a production process with minimal environmental impact. The product should be marketed by its environmental friendly manufacturing in order to build credibility.

A draft check list for minimised environmental impact from the production process was developed inspired by the work by Siljebratt and Abrahamsson [7]:

- Ensure material selection from an environmental perspective. Reused material, non-fossil material, non-fossil material manufacturing and approved chemicals are important elements.
- Optimize the material usage in the manufacturing processes.
- Minimize the number of production steps and use processes that optimize the input goods in relation to rest- and bi-products.
- Minimize production scrap and losses. Control the processes so the product quality is optimized in relation to the specification.
- Ensure that the technical life span is in balance with the functional life span.
- Design the product so components and material can be reused. Any scrap material should be possible to reuse, at least as heating.
- Design the product and packaging so it minimizes transportation needs. Use recycled material for packaging. Define modes of transportation where fuel type and consumption give minimal environmental impact.

4.2 Case 2: Spiralfläkt

Spiralfläkt Svenska AB supplies fans with extremely high energy efficiency. The fan wheels are designed according to the customer's specification and adapted to standardized fan houses.

The objective of this case was to define the manufacturing process concerning the company's only product, the spiral formed fan, illustrated in figure 6. The fans superior energy efficiency is the main advantage in comparison to competitor's fans. The study concerned a resource efficient series production and high flexibility with regard to geometrical dimensions of the fan.

Potential customers were identified and a series production was eminent. The product has not previously been industrially manufactured, but produced in a prototype manner.

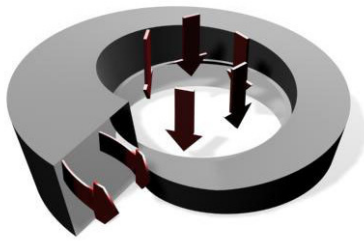


Figure 6. Principle illustration of the Spiral fan.

The project concerned two major parts:

- The assembly process of the sheet metal parts – solution, technology, automation, resource efficiency and minimal environmental impact.
- The industrial system – localization of assembly with environmental impact of alternative solutions.

Also in this case the product was focused on decreasing energy usage at the customer, emphasising the need of minimal environmental impact from the production of the fan in order to build credibility.

From a process of developing a number of alternative assembly principles, a final proposed automated assembly process was presented, as shown in figure 7.

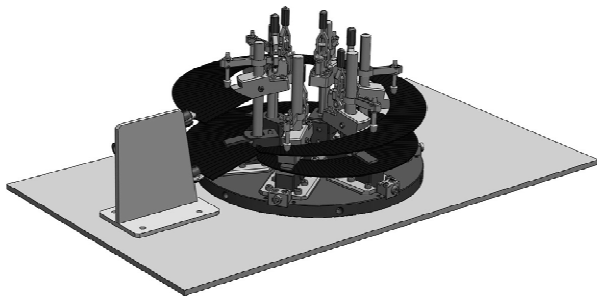


Figure 7. Industrial assembly solution for the Spiral Fan

In this case an industrial assembly solution will lead to improved quality, decreased waste and scrap in comparison to a manual assembly. Also product design to maximize output in cutting or punching of sheet details is relevant.

A company specific guide check list, similar in structure to the one defined for the Power Aware Cord (see section 4.1), was defined for the Spiral Fan.

An area of specific interest for the company is to design the industrial system with an environmental consideration. The study analyzed the possibility to offer the manufacturing of the product to the customer, i.e. provide a possible mobile final assembly cell enabling final assembly close to end customers reducing cost of transport and emission. This could, used in a proper manner, lead to substantial reductions in transportation costs and emissions from ready fans, since the fans can be of substantial size. However, the order volume and fan size are two critical parameters in deciding upon local on-site assembly or delivering assembled fans.

4.3 Case 3: Alfdex

Alfdex is a joint venture by Alfa Laval and Haldex to develop and produce separators for crankcase ventilation, shown in Figure 8, of which the first generation is already launched and in use and the second generation is under development.

As the environmental issues and global warming have been brought to concern by governments and private sectors, emission regulations has become tougher and stricter. Korea was the first country to legislate about crankcase emissions and it is no longer allowed to release the emissions directly into the environment. Japan and USA have issued similar regulations and the European Union (EU) is about to follow. As a result of these regulations, crankcase ventilation with better separation performance for trucks is needed. The product from Alfdex is a cost-efficient ventilation product with superior environmental performance.



Figure 8. The Alfdex crankcase gas separator

The objective of this case was to investigate the current product's production and other areas of interest in the supply chain to provide improvement opportunities in current and future production. The focus was to create a climate smart production system and should present a check list for the company.

The case was conducted in following phases:

1. Process description with process mapping, layout, equipment, materials handling and logistics and information and process control/planning.
2. Product description
3. Work force and capacity with working times, ergonomics, production volumes and volume variation.
4. Time study with cycle time, lead time, bottle necks, losses, reconfiguration and maintenance, Overall equipment efficiency.
5. Environmental effect analysis according to Eco-indicator '99 as well as EPS-system (section 2.2).

In summary, following improvement suggestions were given by the external researchers:

1. Potential improvements within production

- Schedule the test for a critical component earlier in order to minimise used effort and energy in the production processes.
- Reduce leaking of compressed air or consider another technology, consuming less energy. Use a leak finder agent which give lower effect on environment i.e. harmless for aquatic organisms, non-irritate for eye and skin.
- Improve the efficiency of a critical bottle-neck cell and sufficient buffer should be built, in order to prevent interruption of the production lines.
- Concept of total productive maintenance (TPM) should be further introduced in order to maximise equipment efficiency that will assist the company to reduce or eliminate equipment downtime, speed losses and defects.

2. Evaluate material supplier

- Potential improvement for new supplier
- Locate a supplier closer to Alfdex site
- Encourage the supplier to use production technologies that minimizes environmental impact i.e. more effective energy consumption, less emission rate

3. Change mode of transportation or combine road mode and rail mode

Currently all transport of Alfdex both inbound and outbound is done by road mode (truck). Freight train uses only 20% of truck energy consumption for the same distance.

<u>Pros</u>	<u>Cons</u>
Less emission	Might lead to less flexibility and longer lead time
Potential cost reduction	Need more changeover/transfer work

4. Apply more automation in production line

<u>Pros</u>	<u>Cons</u>
Increase productivity	Investment cost Energy consumption
Reduce human error	Increase non-recycle waste i.e. electronic parts in machines
Potential improvement in terms of quality rate	Machines and production system will become more sophisticate and might need higher skilled staff to handle maintenance work.

5. Partial assemble separator unit close to large market

<u>Pros</u>	<u>Cons</u>
Shorter lead time	Investment cost
Potential to increase customer satisfaction level	Increases complexity in administration
Existing market and customers	Might lead to low productivity and quality rate during learning period
Potential to find new customers	
Potential in reducing overall emission from transportation	
Availability of aluminium suppliers and plants close to customer sites	

Besides the suggestions above, a checklist of a climate smart production system was prepared in order to provide the company's idea and guideline to achieve the following points:

- Reduce or eliminate emission rate from its products and supply chains.
- Increase efficiency of energy consumption or reduce consumption rate within their production.
- Cause less pollution and waste to environment
- Increase efficiency of resources consumption
- Reduce environmental effect from design state

5 SUMMARIZING INTO AN ANALYSIS SCHEME

On the basis from the three cases and inspired from the work by Siljebratt and Abrahamsson [8], a draft analysis scheme for designing a more environmentally sustainable production system have been designed. The structure has been segmented in 9 subsections where also the product design has been included for completeness reasons.

5.1 Product design

Optimise functions that the product can provide

- Integrate several functions in the same product that can give the result to total environmental load factor

such reducing material resource, energy consumption, and/or transportation.

- Make the product smarter with functions that need/require less material.
- Pay attention to service functions of the product that is in interest and try to increase effectiveness in resource management that can give lesser environmental effect. Besides it can provide bigger economic opportunity.
- The products should be simple and easy to maintain and repair.

Use more environmental friendly material

- Perform LCA analysis
- Describe life cycle scenario to support the evaluation both in term of environmental and business point of view.
- Select material and chemical substances that have less influence on the environment by considering the whole lifecycle of the material and the chemical substances. Public restriction lists are available.
- Decrease using materials that are non-renewable or are rare commodities. Examples of renewable resources are sun, wind and waterpower, industrial forest that can be grown.
- Reduce the number of materials and substances that causes emissions to produce. Also increase efficiency in the production process to reduce released emission to air and water.
- Use recyclable material as long as possible as in general it will give less environmental influence than get the new material.
- Make sure that all materials are recyclable or reusable and that no material is incompatible with the others.

Reduce material consumption

- Try to thoroughly reduce the number of material by reducing both in term of cost and energy consumption. Use DFX-tools during the development process of product.
- Design products in order to reduce transportation volume as much as possible in order to minimise transport need for the product.
- Apply/adjust the material after the plan useful life of product.
- Use simulation program to assist in the design process to minimise waste from material.

5.2 Policy

- Have clear and reasonable goals and policies regarding environmental issues.
- Apply lean thinking in order to maximise efficiency of resource usage and continue improvement to achieve better result in an environmental viewpoint.
- Follow up the environmental study and new regulations on this area then transfer/link to the company policy and guideline.

5.3 Supplier

- Select suppliers who locate close to company production site.
- Choose suppliers who have environmental certification/is environmentally conscious.
- Minimise/eliminate use of substances in concern (black and grey list of substances).
- Production technology and resources of suppliers should be taken in consideration under supplier selection process. Should choose suppliers that are more effective and give less environmental effect whenever possible.

5.4 Transportation and logistics

- Use environmentally friendly transportation mode i.e. rail, ship instead of lorry whenever possible.
- Formulate green logistics guidelines and strengthen cooperation with transport carrier.
- Optimise number of trips to satisfy the customer requirements/provide sufficient material to the production line while minimising the number of trips.
- Use/buy Ultra Low Sulfur diesel if possible for the company's vehicles (if applicable).
- Reduce use of packaging and wrapping material.
- Use reusable packaging, pallets and such, instead of cardboard boxes.

5.5 Energy

- Buy electricity that is generated from environmental friendly sources such as wind, water, solar cell.
- Promote the energy saving habit for employees turn off / shutdown light, machines and equipment when they are not in use.

5.6 Production process

- Design production layout in order to minimize unnecessary trips of the production staff and logistics activities.

Use better environmental friendly production method

- Reduce the environmental load from the production processes i.e. using technology that give less environmental effect such as apply water based solvent instead of benzene based.
- Minimise total number of production processes with help of better management and logistics such as a good storage in proper temperature so the product do not need to have oil removing or blasting.
- Use the production processes so that input can be optimised to become the product by taking action at the source, such as reduce losses and wastes within every production processes, improve yields and other measurement.
- Ensure that the products fulfil high quality level in order to optimise the output.
- All support and administrative functions should be effective otherwise could lead to cassation of products.
- Ensure that the production comply with a good and satisfying working environment.

5.7 Machine and equipment

- Choose energy saving machines and equipment
- Lease/use hybrid and/or electric vehicles for the production whenever possible.
- Reuse and recycle own machine/equipment whenever applicable.
- Provide proper maintenance in order to keep the machines and equipment in perfect working condition and avoid interruption in production process that will decrease efficiency.

5.8 Waste management

- Minimise waste
- Promote internal reuse
- Separate/ sorting wastes by type
- Ensure that recycle bins are located in convenient and easily accessible locations on set and in production offices

5.9 Miscellaneous-working media

- Go paperless whenever possible utilizing electronic forms of communication. Only print script on demand.
- Use Tablet PCs or digital dailies; e-mail revised scripts

- Use certificated renewable/sustainable building material for set construction.
- Use paints, sealants and lacquers that are low-emission and less toxic.
- Use bio-diesel fuels for all auxiliary power generations (if applicable).
- Use non toxic cleaning products and buy unbleached, high recycled content items for production office supply.
- Reuse or donate unwanted production materials and supplies.
- Arrange for all materials and office equipment to be recycled or donated. Coordinate with non-profit and local schools before production end.
- Recycle production office material (paper, plastics).
- Ensure that food and beverage supplier provides reusable, recyclable, and/or biodegradable serving product instead of Styrofoam and plastic.
- Request that caterers provide food that is locally sourced and is organic or sustainable.
- Arrange food bank to pick up leftover food at the end of each day.

6 DISCUSSION

The cases represent companies where environmentally conscious actions need no longer be seen as challenges and contrary to financial considerations. On the contrary, it is the basis for successful products and companies.

The aims of the cases were to provide potential suggestions and checklist in order to assist the companies to create a strategy on how to develop, produce and supply their environmental friendly products in an environmental friendly way both in the present and in the future. The current state analysis and environmental assessment have been performed to identify potential improvement areas. Value Stream Mapping, Processes Flowchart, Life Cycle Analysis (LCA), Overall Equipment Efficiency, Green design and production, Lean production system and Total Productive Maintenance were used as the basis tools and methodologies for the analysis and assessment. In addition, workshops, discussions and consulting with scholars in relevant areas have been held to provide more input and reflections on the cases.

The suggestions are generated based on the analysis and environmental assessment results. There are a number of potential improvements for the companies to become a more environmental friendly production system. Proposals have formed in main areas, e.g. for the Alfdex case there are improvement within production, supplier selection, transportation mode, applying of automation, and new production site that is closer to the market. The implementation of suggestions could be done separately one by one or by combining several suggestions together.

The draft analysis scheme for climate smart production system have been prepared and categorised into steps along the production process from design of product to waste management. The analysis scheme can be used as the guideline and environmental reminding kit.

By applying our proposals and following the analysis scheme, the companies might gain potential benefits as follow:

- Reduce or eliminate emissions, pollution and waste to environment.
- Increase efficiency of energy and resources consumption.
- Reduce environmental effect from design stage.
- Increase marketing and competitive opportunities from a good image on environmental consciousness.
- Cost reduction.
- Increase production efficiency.

The need for environmental sustainability creates both restrictions and opportunities for the manufacturing industry. Products and transports/logistics have been first in focus for environmental impact improvements. However, to reach a total effect, the manufacturing process also needs to be looked upon from an environmental perspective. Process industry has worked with these issues longer than the manufacturing industry due to high energy consumption and potentially polluting processes.

We argue that the most appropriate production process is the most resource efficient. The trick is however to make it appropriate, and thus resource efficient, over time. The concept of lean manufacturing deals with resource efficiency of all kinds, and is closely linked to building a truly sustainable production satisfying the increasing market place.

6.1 Future research needs

On the basis of this first exploratory study of 'green production system design' three main fields of research are identified:

1. Analysis support for environmental sustainable production. To be able to assess and value the environmental impact from current and future production systems. To create a linkage between current key performance indicators, productivity measures, LCA-tools and building a foundation for requirement specification of future production systems. This forms the basis for developing an industrial relevant and applicable decision support tool for sustainable production system design.
2. Design methodology for environmental sustainable production. A working procedure and process with close correlation with existing state of the art production development processes. Tools, guidelines and working sub-procedures should be defined for specific steps of the development of production systems. Deliberations and decision support. To link the development of product and production.
3. Concepts for environmentally sustainable production. We should see examples of the linkage between green products and green production. Demonstrating radically new ways of producing environmentally friendly products by reuse and recycling. Design for sustainable product and production. Preferably in combination with totally new business concepts.

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